

4.0 DEVELOPMENT AND SCREENING OF REMEDIAL ALTERNATIVES

In this section, potential remedial alternatives are assembled using various process options associated with SVE, which was selected as the presumptive remedy in Section 3.0 (refer to Subsection 3.3.1). The potential remedial alternatives are then subjected to a screening process in which their effectiveness, implementability, and cost are evaluated. The retained remedial alternatives are subjected to a more detailed evaluation in Section 5.0 using the nine Superfund evaluation criteria. Also included in this section is a description of the SVE pilot test conducted at OU-2, and a summary of the results.

The final configuration of the remedial alternative selected for implementation will be based on performance criteria presented in the ROD. Any additional information and data acquired during remedial design, such as from pilot testing, will also be considered when the final design is developed. The project details described in this FS are conceptual and have been assumed only for cost estimating and remedial alternative comparisons. Other technologies and configurations are possible. In accordance with EPA guidance, cost estimates developed at this stage in the FS process are approximate (plus 50 to minus 30 percent), and based on designs that are not yet well defined.

4.1 DEVELOPMENT OF REMEDIAL ALTERNATIVES

The development of alternatives must conform to requirements identified in CERCLA, as amended, and to the extent possible in the National Contingency Plan (40 CFR Part 300). CERCLA Section 121(b) identifies the following statutory preferences when developing and evaluating remedial alternatives.

- Remedial actions that involve treatments that permanently and significantly reduce the volume, toxicity, or mobility of contaminants or hazardous substances are preferred over alternatives that only prevent exposure.
- Off-site transport and disposal of hazardous substances or contaminated materials without treatment is considered the least favored remedial action for sites where practical treatment technologies are available.
- Remedial actions using permanent solutions, innovative treatment technologies, or resource recovery technologies shall be assessed.

These requirements will be taken into consideration in developing the alternatives for the JPL site.

For the purposes of this FS, the remedial alternatives consist of process options associated with treatment of VOC waste streams extracted via SVE. SVE is paired with the various process

options to form remedial alternatives, which are then screened on the basis of effectiveness, implementability, and cost.

As per EPA guidance, the "No Action" alternative is carried through the FS screening processes to provide a baseline for comparison with other alternatives. The "No Action" alternative consists of leaving the site "as is." Under this alternative, no remedial activities would be undertaken at OU-2 in the future, and the pilot plant currently operational would be taken off line.

Based on the analysis presented in Section 3.0 and above, the general alternatives for OU-2 at JPL include:

- No Action
- In Situ Soil Vapor Extraction

These alternatives include soil-vapor monitoring via the quarterly monitoring program (currently in place) to assess the VOC concentration trends over time.

As noted above, additional technologies that are required for treatment of waste streams from SVE are considered below. Vapors extracted from the well(s) will contain VOCs, and the vapor stream will require treatment prior to discharge to the atmosphere.

Using the EPA *Remediation Technologies Screening Matrix and Reference Guide* (EPA, 1993c), the following technologies were identified as being appropriate for VOC removal from the off-gas stream:

- Thermal Oxidation
- Catalytic Oxidation
- Carbon Adsorption
- VOC Adsorbing Resins

The choice of off-gas treatment method may depend on the concentrations of contaminants and may change if these concentrations vary by an order of magnitude, either across the site or with time.

4.1.1 Development of Alternatives

Alternatives were developed using the "No Action" alternative, and in situ SVE (the presumptive remedy) plus the possible process options for treating waste streams. As noted above, all alternatives include soil monitoring, so that the degree of remediation can be evaluated. Natural attenuation will occur regardless of human effort; therefore, it is expected to occur to some extent in each alternative as well.

Four alternatives were developed for SVE, each specifying a different process option for off-gas treatment.

The alternatives developed for consideration at JPL OU-2 are:

Alternative 1:	No Action
Alternative 2:	In Situ SVE Treatment
Alternative 2a:	Thermal Oxidation Off-Gas Treatment
Alternative 2b:	Catalytic Oxidation Off-Gas Treatment
Alternative 2c:	Granular Activated Carbon Adsorption Off-Gas Treatment
Alternative 2d:	VOC Adsorbing Resins Off-Gas Treatment

4.2 PILOT TEST

In situ SVE was identified during the RI stage as being a potentially feasible technology for remediation of the VOC-impacted soils in OU-2. Implementation of in situ SVE requires collection of site-specific data, typically through implementation on a field pilot scale. This was recognized by the RPMs during the RI process, and a field scale pilot test was implemented starting in April of 1998. This testing confirmed the feasibility of in situ SVE in remediating VOC-impacted soils, and provided design parameters for future full-scale implementation. Detailed descriptions of the pilot test and results obtained to date are provided in Appendix A. A summary of relevant information is provided in the following sections.

4.2.1 Test Setup

The pilot test was performed on a test vapor extraction well (VE-1) installed at the location shown in Figure 4-1 that is at the approximate center of the area with the highest VOC concentrations. The well is screened across the depth of contamination, from approximately 45 feet bgs to 185 feet bgs. It consists of three discrete casings that are screened at different depths [Screen A (44 to 84 feet bgs), Screen B (94 to 134 feet bgs), and Screen C (145 to 185 feet bgs)] as shown in Figure 4-2. This allows a better distribution of vacuum across the screened interval and allows for extraction from specific depths as opposed to the entire screened depth.

The test consisted of applying a vacuum on various combinations of these casings, monitoring flow rates and VOC concentrations in extracted vapors, and measuring vacuum responses in the soil vapor monitoring wells surrounding VE-1. Locations of the wells that were monitored are shown in Figure 4-1. As noted in the RI report (Foster Wheeler, 1999b), each well consists of multiple soil vapor sampling tips at various depths. These wells were also monitored for VOCs as part of the ongoing soil vapor monitoring program, which provided additional information in terms of SVE effectiveness. A vacuum blower was used to extract soil vapors from VE-1, and

the vapors were treated with four vapor-phase granular activated carbon (GAC) vessels as shown in Figure 4-3.

The test consisted of a short-term portion (Tests 1 and 2) from April 1998 to June 1998, and a long-term portion (Test 3) beginning in November 1998 (this test is ongoing).

4.2.2 Test Results

The test results indicated that SVE is indeed a feasible technology for remediation of the VOC-impacted soils at OU-2. Following are some of the key results of the pilot test:

- All three screens were able to extract significant quantities of soil vapor with flow-rates ranging from 157 to 174 cfm from each screen at vacuums ranging from 44 to 80 inches of water.
- Vacuum responses were noted as far as 771 feet away from the extraction well. Normalized vacuum responses of greater than or equal to 1 percent of the exerted vacuum were observed at least 460 feet away.
- A 75 percent reduction in CCl_4 (the primary constituent of interest) levels was observed approximately 450 feet away from the extraction well in Zone 4 (approximately the bottom 50 feet of the vadose zone). In Zones 2 and 3, 75 percent reductions in CCl_4 levels were observed 550 and 425 feet away from the extraction well, respectively.
- VOC concentrations in the extracted vapor were reduced by over 95 percent over the duration of the test.
- VOC removal rates of up to 0.10 lbs/hr were noted for CCl_4 , with an overall removal of approximately 180 lbs of CCl_4 between May 1998 and October 1999.
- Total VOC removal rates of up to 0.11 lbs/hr were noted, with an overall removal of approximately 200 lbs between May 1998 and October 1999. An additional 850 lbs of VOCs (total) may have been removed on two separate occasions.

4.2.3 SVE Effectiveness

As noted above, vacuum responses were noted as far as 700 feet away from VE-1 during the early portions of the test, indicating a ROI of at least 700 feet. This is somewhat higher than the typical ROI at most sites (10 to 200 feet depending on soil type). This led to an extension of the test from an originally intended duration of 10 weeks, to approximately 12 months. Furthermore, the observation of vacuum responses does not necessarily imply that remediation (i.e., removal of VOCs) is occurring within the area encompassed by the ROI. Hence, the actual changes in VOC levels in the various soil-vapor monitoring probes were evaluated over time to provide a better measure of SVE effectiveness. This effectiveness was measured in terms of the radius of remedial influence (RORI), which is defined as the distance (from the extraction well) which significant reduction in VOCs (as evidenced by soil vapor levels) is observed.

Four soil-vapor monitoring events (May/June 1998, October 1998, March 1999, and October 1999) were used to evaluate SVE effectiveness. It is noted here that two events were actually conducted in May/June 1998. However, because they were conducted only one month apart, they were considered together for the purpose of assessing SVE effectiveness, and the highest concentration for each sampling probe was used. VOC levels (CCl₄ and Freon) for the four events for selected soil vapor monitoring probes are shown on Figure 4-4. Based on Figure 4-4, VOC levels have reduced significantly as a result of the SVE pilot test. Contours for CCl₄ and Freon are shown in Figures 4-5 and 4-6, respectively, for the four events. These figures also reflect the significant reduction in VOC levels as a result of the pilot test.

As shown in Appendix A, reductions of greater than 50 percent were observed as far as 340 and 380 feet away from the extraction well for Freon in Zones 3 and 4. The corresponding distance for Freon in Zone 2 is greater than 1,000 feet. The effectiveness for CCl₄ is greater than for Freon, with a 75 percent reduction occurring at approximately 550, 425, and 450 feet for Zones 2, 3, and 4, respectively. To be conservative, a RORI of 400 feet is assumed.

4.3 SCREENING OF REMEDIAL ALTERNATIVES

In this section, the remedial alternatives listed above are described and evaluated on the basis of effectiveness, implementability, and cost, the same criteria used in Section 3.3. The focus of the following screening is enlarged to include the effects of the remedial process on its surroundings as well as its technical feasibility. Alternatives with favorable composite evaluations will be retained for further consideration during the detailed analysis presented in Section 5.0.

Effectiveness—The effectiveness criterion evaluates the ability of an alternative to provide protection to human health and the environment. This includes both immediate and long-term considerations. According to EPA guidance (EPA, 1988a), the effectiveness screening includes the following criteria:

- The ability to protect the groundwater beneath the site, i.e., meet cleanup levels for soil that are protective of beneficial use of the groundwater.
- The degree of permanent reduction in toxicity, mobility, or volume.
- The magnitude of risks to the public, site workers, or the environment during implementation.
- The ability to attain remediation goals.

It should be noted that evaluating effectiveness with regard to direct protection of human health is not required for soils at this site because the risk assessment found no human health risks associated with surface soils [OU-2 RI report (Foster Wheeler, 1999b)]. In addition, mitigation of potential human health risks due to exposure to contaminants via groundwater is the subject of the OU-1/OU-3 FS (Foster Wheeler, 1999c).

Implementability—Implementability is a measure of both the technical and administrative feasibility of each alternative, particularly with respect to construction, operation, and maintenance. Implementability criteria include the following:

- The extent to which a process can be constructed, reliably operated, and meet technology-specific regulations
- How easily operation, maintenance, replacement, and monitoring of technical components can be achieved after the remediation period is complete.
- The difficulty in obtaining approvals from other offices and agencies.
- The availability of treatment, storage, and disposal services and capacity.
- The requirements for, and availability of, specific equipment and technical specialists.

Cost—During the alternative screening, order of magnitude cost estimates are used to provide comparisons between alternatives, rather than to define the cost of specific alternatives. The following considerations are used for the cost screening at this level:

- Comparative cost increase or decrease with respect to the benefit derived from one alternative versus another.
- Comparative capital and operation and maintenance (O&M) costs for the alternatives.

4.3.1 Alternative 1: No Action, Monitoring

The No Action alternative is evaluated for this FS in accordance with NCP protocols (40 CFR Part 300). This alternative stipulates that no additional remedial activities will be implemented by JPL. Under this alternative, no remedial activities are undertaken at the site, the current SVE pilot system is taken off-line, and a soil-vapor monitoring program is instituted to assess temporal changes in contaminant concentrations and distributions.

Advantages and disadvantages of the No Action alternative are evaluated in the following paragraphs.

Effectiveness—This alternative does not provide protection of groundwater, since there are no provisions to prevent the VOC plume from continuing to migrate to the water table. No reduction in toxicity, mobility, or volume of contaminants will result from this alternative with the exception of incidental reductions in volume or toxicity due to natural processes.

There are no risks to the public, site workers, and the environment resulting from implementation of this alternative, since no actions will take place. Remediation goals will not be met in the foreseeable future if no action is taken.

Implementability—The No Action alternative is easily implemented since no new construction is required. Soil-vapor monitoring will require field operations similar to those undertaken during

the RI and is already proven to be technically implementable at this site. In addition, soil vapor sampling tips are already in place for future soil vapor sample collection.

The No Action alternative is not likely to be acceptable to local governments and the public because the VOC plume will continue to act as a source of groundwater contamination. As discussed in the JPL OU-1 and OU-3 FS report (Foster Wheeler, 1999c), this groundwater may impact surrounding communities if no remedial action is taken.

Cost—The only costs associated with the No Action alternative are those for the soil vapor monitoring program. These fall into the O&M category, and will continue periodically for at least 5 years.

Conclusion—The No Action alternative represents the baseline to which all other remedial alternatives are compared. Thus, as required by the NCP, the No Action alternative will be carried into the detailed evaluation in Section 5.0.

4.3.2 Alternative 2: In Situ SVE, Monitoring

Under Alternative 2, VOCs in the vadose zone are treated with in situ SVE. As explained in Section 3.3, in situ SVE has been identified by USEPA as a presumptive remedy for sites with VOCs present in soil. Based on discussions presented in Sections 3.3.1 and 4.2, SVE can be performed as an in situ process (thereby increasing economic effectiveness), is amenable to conditions at JPL, and has been shown to be effective at JPL in a pilot study. In situ SVE has, therefore, been selected as the presumptive remedy, and does not require further evaluation in this section. The ongoing soil-vapor monitoring program will be used to assess changes in contaminant concentrations and extent over time.

The soil vapors extracted by the SVE system constitute a waste off-gas stream, and contain the VOCs removed from the vadose zone. These VOCs must be removed before the off-gas can be discharged to the atmosphere. Four different options for vapor treatment are considered, and are evaluated in the following section.

4.3.3 Off-Gas Treatment

Alternative 2 requires off-gas treatment as part of the treatment train. Four off-gas treatment options are evaluated in the following subsections to determine which are most appropriate at this site.

4.3.3.1 Alternative 2a: Thermal Oxidation Off-Gas Treatment

Thermal oxidation is a process in which organic contaminants are destroyed in a combustor at temperatures of approximately 1,800°F (1,000°C). The primary advantage of thermal oxidation is that contaminants are chemically degraded into nontoxic compounds. This process is typically applied to streams with contaminant concentrations greater than 12,000 parts per million by

volume (ppmv). Vapor/liquid separators are used prior to thermal oxidation units to remove noncombustible components from the treatment stream.

Effectiveness—Thermal oxidation effectively removes VOCs, SVOCs, and fuel hydrocarbons from gaseous streams. However, it is typically targeted toward treatment of non-halogenated compounds and can be problematic when used on waste streams containing chlorinated materials such as those present at JPL (EPA, 1993b). This is mainly because hydrochloric acid (HCl) is generated, which is highly corrosive, and can damage various system components. Furthermore, since halogenated compounds are present, the system would be Resource Conservation and Recovery Act (RCRA) regulated as a hazardous waste incinerator, which would require extensive permitting.

Conclusion—All four of the constituents of interest at the JPL OU-2 site are chlorinated, and the presence of chlorine makes thermal oxidation inappropriate for the waste stream at this site due to the production of HCl. Based on low effectiveness, this treatment process is eliminated from further consideration in this FS.

4.3.3.2 Alternative 2b: Catalytic Oxidation (Halogenated) Off-Gas Treatment

Catalytic oxidation uses a catalyst to treat air streams containing halogenated organics, typically at concentrations less than 12,000 ppmv. During treatment, the air stream is preheated to approximately 840°F (450°C) and then passed through the catalyst bed where it is oxidized. The contaminants and oxygen are adsorbed onto the catalyst surface where they react to produce carbon dioxide, water, and hydrogen chloride or hydrogen fluoride gas (for the VOCs at this site). The exhaust typically requires scrubbing (usually with water) to remove the chloride and fluoride, prior to final discharge to the atmosphere.

Effectiveness—While catalytic oxidation can remove halogenated VOCs from an air stream, it may not be able to reach the fairly low levels that would be required by the SCAQMD and may require additional polishing of air stream prior to discharging to atmosphere (typically GAC). The major advantage of this process is that it permanently destroys the contaminants resulting in complete toxicity removal. Since the discharge from the catalytic oxidation system will contain halogenated acids (as halogenated VOCs are the primary constituents of concern), this method will require additional treatment options for addressing halogenated acids (typically scrubbing). Risks to the public and site workers during implementation are well controlled and are negligible if the system is operated correctly.

Implementability—This process has been used successfully in the past, and can be installed and operated reliably. While no permits would be required, the “substantive” requirements of a Permit to Construct/Operate from the South Coast Air Quality Management District (SCAQMD) would have to be met.

The constituents of interest at the JPL OU-2 site are halogenated, primarily with chlorine, but also with fluorine (Freon 113). Emissions from the oxidation unit will, therefore, contain

hydrogen chloride and hydrogen fluoride, and they would require scrubbing prior to discharge to the atmosphere. This would result in another waste stream (water). Also, since the halogenated volatiles do not have a very high calorific value, the catalytic unit will require heat energy (either natural gas or electricity). Some specialized training may be required for operating personnel. Oxidation units are available to treat a large range of flow rates.

Cost—This process option is rated as ‘Better’ by the EPA, indicating that a general cost range, based on past experience, is less than \$7 per pound of off-gas treated (EPA, 1993b). However, this cost does not reflect the additional costs that would be incurred for scrubbing and the significant amounts of energy (gas or electricity) that would be required. Hence, actual costs are expected to be much higher. Typical costs for a 500 cfm system are on the order of \$200,000 (capital), and \$5,000 per month for electricity, chemicals, and laboratory analyses.

Conclusion—Catalytic oxidation could be used to treat VOCs in the off-gas stream from the SVE system. However, additional treatment may be required to scrub hydrogen chloride and/or hydrogen fluoride from system emissions. Additional polishing of the exhaust may be needed to comply with SCAQMD requirements. Hence, this option is eliminated from further consideration in this FS.

4.3.3.3 Alternative 2c: Granular Activated Carbon Off-Gas Treatment

This off-gas treatment process uses GAC to capture contaminant molecules from the gas phase. Typically, the GAC is contained in a packed bed through which the off-gas flows. When the carbon becomes saturated with contaminants, it is regenerated in place or removed and regenerated at an off-site facility.

Contaminants treated by GAC include VOCs, SVOCs, fuel hydrocarbons, and pesticides. This process is most effective for contaminants with molecular weights between 50 and 200, boiling points between 75° and 300°F (24° and 150°C), and on air streams with a low moisture content. Carbon adsorption is typically used when contaminant concentrations are less than 1,000 ppmv and is capable of high removal efficiencies.

Effectiveness—GAC is effective in removing halogenated VOCs from a vapor stream. Constituents of interest at this site have molecular weights ranging from 97 (1,1-DCE) to 187 (Freon 113) and boiling points ranging from 98.6°F (1,1-DCE) to 188°F (TCE). Because removal rates with GAC are high, this process is frequently used to bring contaminated streams into compliance with regulations and will be able to reach the levels required by the SCAQMD. This has been confirmed during the pilot test by laboratory analyses of the treated vapors. One minor disadvantage of GAC is that the contaminants are not initially destroyed. The contaminants are removed from the carbon in a regeneration process during which they typically are destroyed.

Risks to the public, site workers, and the environment during implementation are low. GAC treatment is reliable and is not likely to result in unintentional releases of contaminants to the surroundings.

Implementability—GAC is a commonly used vapor treatment process for halogenated VOCs. Construction and operation are readily accomplished, and equipment is available from several vendors. Regeneration service is usually provided by the carbon vendor. Different GAC systems are available for treatment of a large range of flow rates, and only require limited special training. Hence, GAC systems are considered to be easy to implement.

Cost—This process option is rated as ‘Better’ by the EPA, indicating that a general cost range, based on past experience, is less than \$7 per pound of off-gas treated (EPA, 1993b). Typical costs for a 500 cfm system are on the order of \$60,000 (capital), and \$2,000 per month for electricity, chemicals, and laboratory analyses.

Conclusion—GAC is a viable choice for treatment of the off-gas stream based on selection criteria discussed above and past operating experience. Despite its disadvantages, GAC units typically compare favorably with other off-gas treatment processes and will be retained for further evaluation.

4.3.3.4 Alternative 2d: VOC Adsorbing Resin Off-Gas Treatment

Adsorbing resin treatment systems are similar to GAC treatment systems except that resin systems rely on various synthetic resins to adsorb VOCs rather than activated carbon. In contrast to activated carbon, which will adsorb a wide variety of chemicals, synthetic resins are designed to selectively adsorb particular chemicals or families of chemicals.

Synthetic resins may be regenerated more than 1,000 times without loss of adsorptive capacity, and systems are typically constructed with on-site regenerative systems. This entails two sets of resin beds, one in the adsorption mode and one in the desorption mode. In the desorption process, the adsorbed chemicals are removed by heating and/or the application of a vacuum. The desorbed chemicals are then condensed from the purge stream and recovered.

Effectiveness—Synthetic resins are effective in removing targeted contaminants from the gas stream and would be appropriate for the constituents of interest at this site because they are all from the family of small, halogenated VOCs. One disadvantage of resins is that the contaminants are not destroyed and must be removed from the resin at a later time and further treatment is needed. Synthetic resins typically have a greater tolerance than GAC systems for off-gas streams with high moisture content.

Risks to the public, site workers, and the environment during implementation are low. Resin adsorption systems are not likely to result in unintentional releases of contaminants to the surroundings.

Implementability—Synthetic resin systems have not been widely used for off-gas treatment. Therefore, availability of equipment and materials may be more limited than for GAC. Regulatory acceptance of resin systems may also be more difficult to obtain than for GAC

systems because this is a relatively new application of resin adsorption. Resin systems can be applied for a large range of flow rates and may require some special training.

Cost—This process option is not rated by the EPA in the Technology Screening document (EPA, 1993b); however, synthetic resin systems with on-site regeneration generally have greater capital costs than typical GAC systems requiring off-site regeneration or disposal. Although this may be balanced by lower operating costs for the synthetic resin systems, these systems have not been widely used for off-gas treatment because of the significantly high capital cost. Typical costs for a 500 cfm system are on the order of \$100,000 (capital), and \$3,000 per month for electricity, chemicals, and laboratory analyses.

Conclusion—Synthetic resins are capable of treating halogenated VOCs in dilute air streams. The higher capital cost is a disadvantage compared to GAC (while resin system performance is about the same as for GAC), which, in turn, results in higher operating costs because of the higher costs for regeneration of resins. Because of the higher cost without significant benefit over GAC, synthetic resins will not be considered further in this FS.

4.3.4 Summary of Off-Gas Treatment Evaluation

Of the four off-gas treatment processes considered for the in situ SVE system at JPL OU-2, one has been retained for further consideration. Results of this evaluation are summarized below:

Off-Gas Treatment	Conclusion
Thermal Oxidation	Reject. Not appropriate for halogenated compounds.
Catalytic Oxidation	Reject. Applicable to constituents of interest at this site. Costs are expected to be on the high side. May require additional side stream treatment, as well as polishing.
GAC	Retain. Proven technology, and proven to be effective for VOC treatment. Applicable to constituents of interest at this site. Less costly compared to other appropriate technologies reviewed.
Synthetic Resin	Reject. Limited performance data. High capital cost with no appreciable benefit in performance over GAC.

Hence, GAC is the preferred treatment for the VOC-containing soil vapors.

4.4 RETAINED ALTERNATIVES

Two alternatives, one consisting of SVE as the presumptive remedy with four variations in terms of off-gas treatment, have been evaluated. The alternatives are developed in more detail in Section 5.0. A more detailed evaluation is then performed to select the preferred alternative for remediation at the JPL OU-2 site.

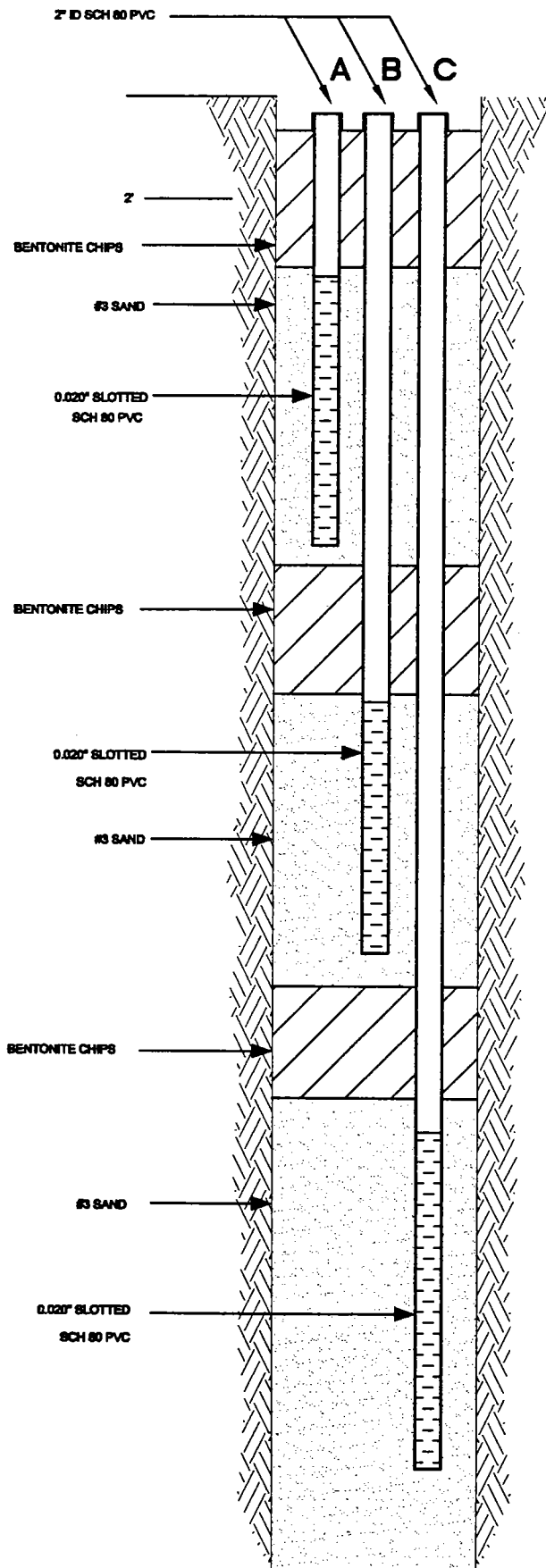
The alternatives retained for further consideration are listed in the following table.

RETAINED ALTERNATIVES	
Alternative	Description
Alternative 1	No Action
Alternative 2c	In Situ SVE/GAC Off-Gas Treatment

In reviewing these alternatives against the statutory preferences identified in CERCLA and listed in Section 4.1, it can be seen that:

- Alternative 2c involves treatment that permanently and significantly reduces the volume of contaminants in soil. This is preferred over alternatives that prevent exposure only, of which there are none at this site.
- Alternatives that do not include off-site transport and disposal of hazardous substances or contaminated materials are preferred over those that do. None of the alternatives at JPL OU-2 include off-site transport of untreated materials.
- Remedial actions included in Alternative 2c incorporate permanent solutions and innovative treatment technologies (i.e., in situ SVE), which are preferred over other approaches.

Therefore, the alternatives being carried forward for further consideration at this site are in compliance with the CERCLA preferences.



SCREEN A: 44' TO 84' BGS
SCREEN B: 94' TO 134' BGS
SCREEN C: 145' TO 185' BGS

I:\1572-JPL\DWG\FS8-00\FIG4-2.DWG
PLOT/UPDATE: MAY 11 2000 10:06:33

FIGURE 4-2

VAPOR EXTRACTION WELL
VE-1

Jet Propulsion Laboratory
Pasadena, California



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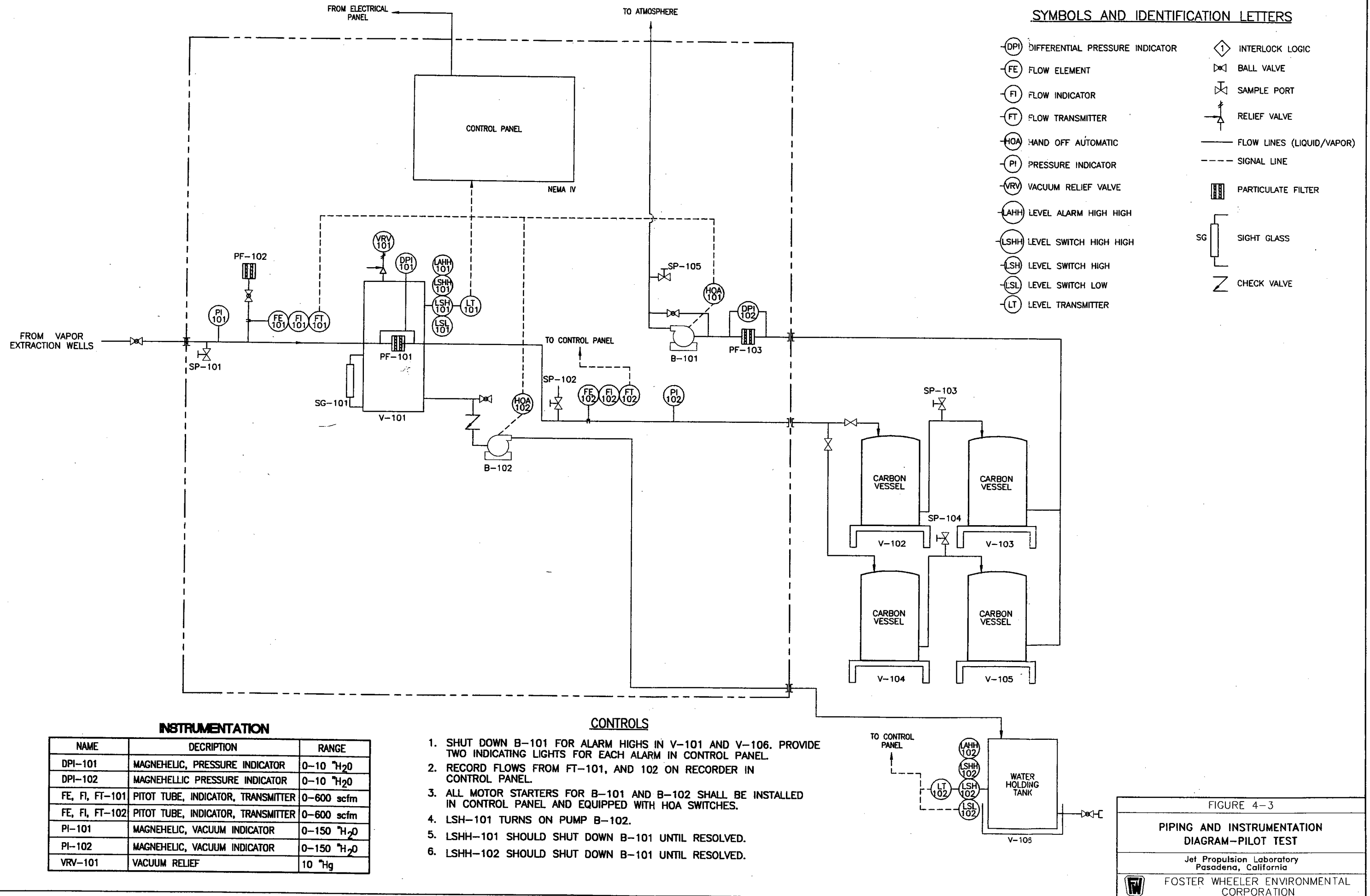
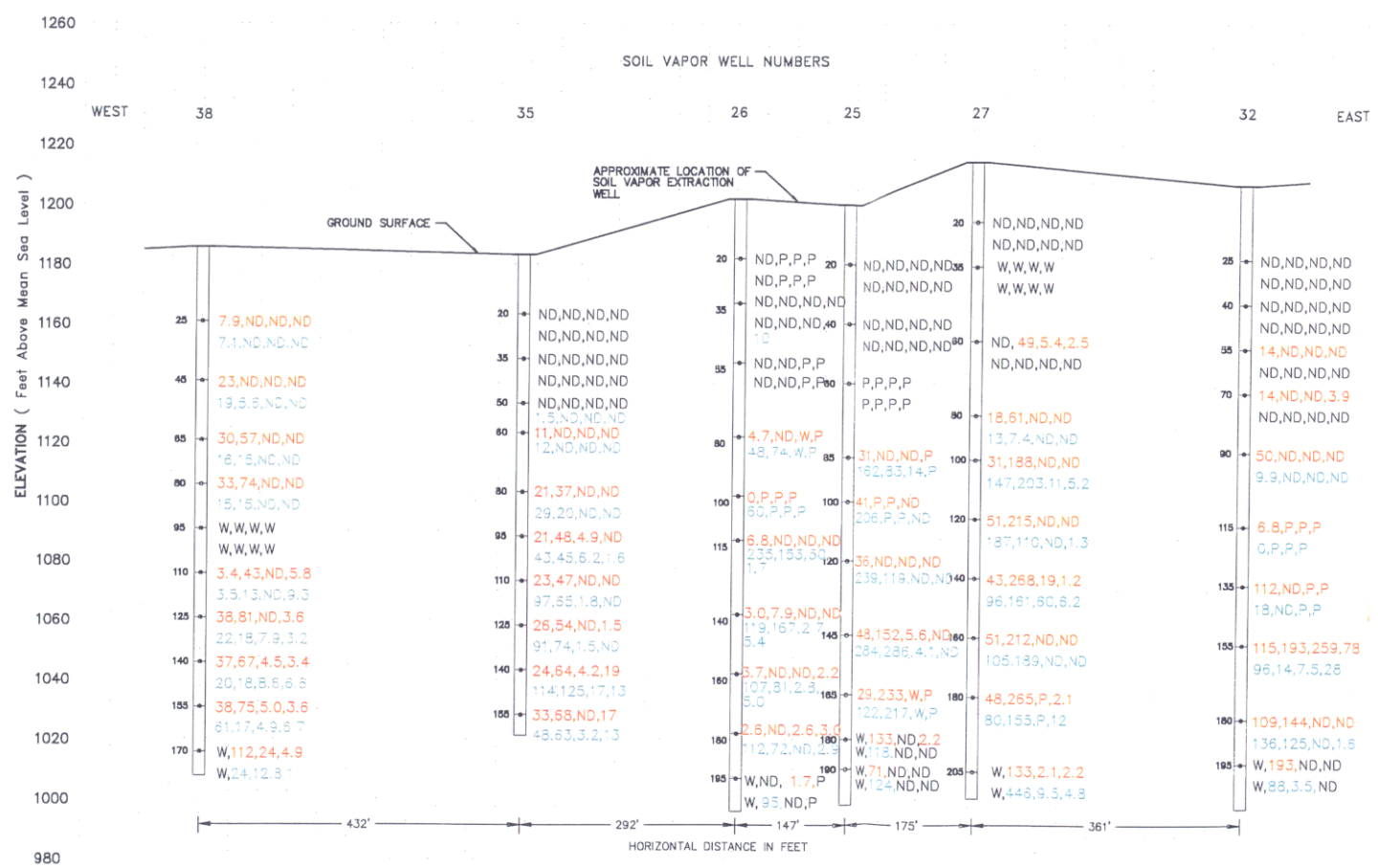


FIGURE 4-3

PIPING AND INSTRUMENTATION
DIAGRAM-PILOT TEST

Jet Propulsion Laboratory
Pasadena, California

FOSTER WHEELER ENVIRONMENTAL
CORPORATION



Explanation

25 + Soil Vapor Sample Point and Depth
ND Non-Detect @ Laboratory Detection Limit of 1.0 μ g/L-Vapor
P Sample Port Plugged; No Sample Collected
W Sample Port Waterlogged; No Sample Collected

MAY/JUNE 1998*
OCTOBER 1998
MARCH 1999
OCTOBER 1999

13,7,4, ND,ND
MAY/JUNE 1998*
OCTOBER 1998
MARCH 1999
OCTOBER 1999

21,37, ND,ND

31 Total Freon 113
162 Total Carbon Tetrachloride

Notes:

Location of cross-section is shown on Figure 4-1.
See section 4-2 for pilot test details.
*Highest concentration from OU-2 RI soil-vapor sampling Events 6 (May 1998) and 7 (June 1998) is shown. Soil Vapor Well Nos. 25, 26 and 27 were not sampled during Event 7.

HORIZONTAL SCALE: 1"=160'
VERTICAL SCALE: 1"=40'

FIGURE 4-4
CONCENTRATIONS OF CARBON TETRACHLORIDE AND
FREON 113 OVER TIME DURING SOIL VAPOR
EXTRACTION PILOT TEST
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